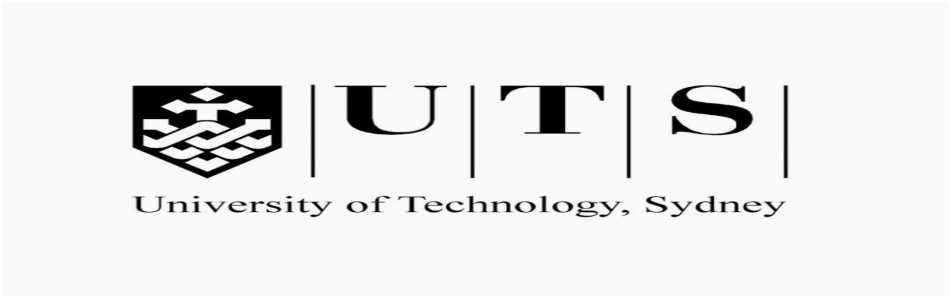


# Investigation to the Ride and Handling of Vehicle with Interconnected Suspensions

by

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A thesis submitted in fulfillment of the requirements for the degree of

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# CERTIFICATE of ORIGINAL AUTHORSHIP

I certify that the work in this thesis has not previously been submitted for a degree nor has it been submitted as part of the requirements for a degree except as fully acknowledged within the text.

I also certify that the thesis has been written by me. Any help that I have received in my research work and the preparation of the thesis has been acknowledged. In addition, I certify that all of the information sources and literature used are indicated in the thesis.

Signed:

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**Guangzhong Xu**

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# ABSTRACT

Conventional passive suspension design often requires a trade-off between ride and handling performance. The unique mode-decoupling property of interconnected suspension presents great potential to improve the compromise between ride and handling. In this thesis, some variants of hydraulically interconnected suspension are presented such as Roll-resistant Hydraulically Interconnected Suspension (RHIS), Pitch-resistant Hydraulically Interconnected Suspension (PHIS), Roll & Pitch Independently Tuned Interconnected Suspension (RPITIS) and Zero Warp Hydro-Pneumatic Interconnected Suspension (ZWHPIS) in order to fully explore the benefits of mode-decoupling and demonstrate the design flexibility of interconnected suspension.

The static property studies of the proposed interconnected suspensions are performed using the fixed vehicle chassis model integrated with the static fluidic model. The characteristics of suspension stiffness and damping are compared with the conventional suspension. Results illustrate that desired mode properties are achieved with the proposed interconnected suspensions. The roll stiffness and damping are favourably increased by the RHIS while the bounce, pitch and warp mode performance are almost unaffected. The pitch stiffness and damping are improved by the PHIS while the influences on the other suspension modes are neutral. The roll and pitch stiffness and damping can be independently tuned by the proposed RPITIS suspension to improve vehicle handling performance while the ride and road holding performance can be further improved with reduced suspension spring stiffness. The off-road vehicle requires suspension warp that is as soft as possible so as to improve the road holding performance. The static property of the ZWHPIS system shows zero warp stiffness is achieved without reducing the ride and anti-roll performance.

Investigations of the ride and handling dynamic performance of the vehicle with various proposed interconnected suspensions are undertaken with a multi-degree rigid body vehicle model coupled with the fluidic model both in the frequency domain and time domain. The linearized models are used in the frequency domain analysis assuming small vibration around the equilibrium position. Modal analyses of the proposed suspension systems are conducted and the results are compared with the conventional suspension. It proves that the decoupled suspension modal properties can be realized favorably through the selected interconnected suspensions. The trends of the ride and handling performances of the vehicle equipped with the proposed suspensions are examined by the frequency response analysis under road inputs or force moments induced by vehicle accelerations. The time domain studies are also performed using the 14 degree-of-freedom nonlinear vehicle model coupled with the nonlinear fluidic model so that more accurate vehicle response can be predicted under complex road conditions and extreme driver maneuvers. The dynamic vehicle responses are compared with a reference vehicle equipped with conventional suspension. The promising improvements both for ride comfort and handling/stability are demonstrated in the simulation results.

The experimental verification of the theoretical modelling of a vehicle with RHIS is performed by bench testing in our suspension lab. Generally, the testing results agree well with the simulation results, especially the tyre dynamic loads under warp mode excitation. The un-modelled effects are discussed and further works are suggested.